

Coastal Engineering Technical Note

ATLANTIC COAST WATER LEVEL PREDICTIONS

PURPOSE: To inform coastal engineers of the availability of the Waterways Experiment Station WIS Report 7, "Atlantic Coast Water-Level Climate," (Ebersole, 1982), and to provide guidance on its use. The initial distribution of this report is only one per district and division because of the report's large size.

BACKGROUND: Selection of a design water level for use in coastal projects is often a difficult task when there is a lack of reliable historic data. Use of a design level which is easily exceeded may result in failure of the project, while a conservative selection of design water level results in additional project cost. Therefore it is to the coastal engineer's advantage to be able to predict the probability of a water level being exceeded at a specific site. This probability must include the combined effects of astronomical tides and storm surge. For example, the occurrence of a storm surge concurrent with a spring high tide will produce a substantial water level rise, but will have a small probability of occurring.

ATLANTIC COAST WATER LEVEL STATISTICS: The Wave Information Study (WIS) has developed water level statistics for selected sites on the U.S. Atlantic Coast. The raw data used in the study are comprised of historical water-level records from 20 National Ocean Survey (NOS) tidal reference stations. The 20 sites are listed below.

Sites of Available Water-Level Predictions

Eastport, ME	New London, CT	Hampton Roads, VA
Bar Harbor, ME	Montauk Pt., NY	Southport, NC
Portland, ME	Willets Pt., NY	Charleston, SC
Seavey Island, ME	The Battery, NY	Fort Pulaski, GA
Boston, MA	Sandy Hook, NJ	Mayport, FL
Woods Hole, MA	Atlantic City, NJ	Miami Beach, FL
Newport, RI	Lewes, DE	

The reference datum for these statistics is the *yearly mean sea level* at each tide station.

The water level probabilities are for combined astronomical tide and storm surge which are assumed to be statistically independent. It is very important to note that these statistics do not include storm surges due to tropical storms (i.e., hurricanes). Future reports will deal with water levels due to combined astronomical tides and extreme tropical storm surges.

PRODUCTS OF WIS REPORT 7: WIS Report 7 presents four statistical water level products for each of the 20 selected sites. Recommendations are given in Report 7 for extrapolating these data to sites between stations. Each of the four products is illustrated and discussed below, and numerical examples are given where appropriate.

1. Monthly and Yearly Mean Sea Levels. Figure 1 illustrates how the monthly and yearly values of mean sea level have fluctuated over the past 60 years in Charleston, South Carolina. The variation of the yearly mean is attributed to tropical and extratropical storm events. Figure 1 seems to illustrate a trend of a long term rise in sea level at Charleston; and, if such were the case, it may be important in determining design criteria for long-life coastal projects. The mean sea level axis refers to elevation above the tide gage zero reference. *However, the analyses in Report 7 did not delve into the stability of or accuracy of the datum plane (or tide gage zero reference); consequently, no conclusions should be drawn from Report 7 data regarding the rate or even the veracity of a postulated sea level rise. Close inspection of Figure 1 reveals that data from 1948 to the present do not, in themselves, reveal an obvious tendency for a sea level rise.

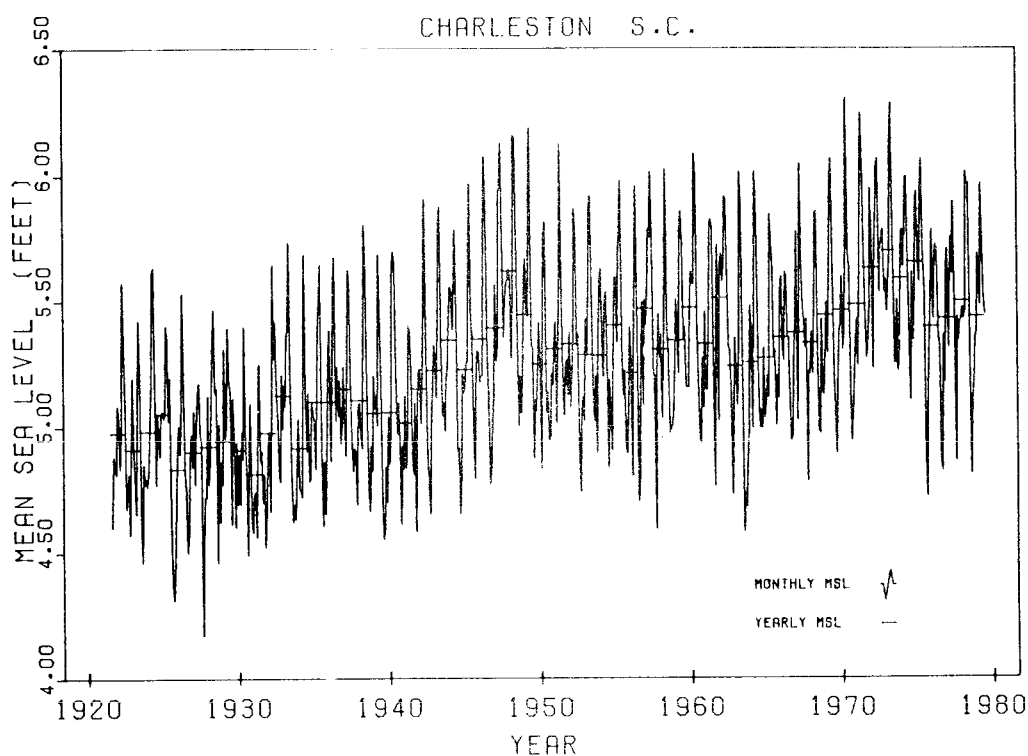


Figure 1: Example of Mean Sea Levels.

2. Probability Density and Cumulative Distribution Statistics. These tables provide the monthly and yearly water level probability statistics for each station. Each table gives interval probability, $P(X)$, and the cumulative probability, $F(X)$, for astronomical tides, storm surge, and combined tide and surges. The elevation reference (X) on these tables has units of feet. Report 7 cautions about using the portion of the probability functions relating to large positive elevations. Figure 2 (yearly statistics) illustrates the format of these tables and is used for the following example.

Required: Find the probability that the total water level will exceed 1.6 feet above mean sea level in any one year at Mayport, Florida.

Solution: The probability, $F(h < 1.6)$, that the water level will be below 1.6 feet is found from Figure 2 under the "Total Water Level" heading. For $X = 1.60$, $F(h < 1.6) = 0.8021$. Therefore the probability that the water level will be above 1.6 feet is $F(h > 1.6) = 1 - F(h < 1.6) = 1 - 0.8021 = 0.1979$ or about 19.8 %.

Linear interpretation of values is performed in the same fashion as in CETN-I-13 (Calculating Tidal Elevation Probabilities).

HAYPORT, FLA.

YEARLY STATISTICS

ASTRONOMICAL TIDE				STORM SURGE				TOTAL WATER LEVEL			
MEAN 0.00		STND DEV 1.67		MEAN-0.01		STND DEV 0.43		MEAN-0.02		STND DEV 1.73	
I	X	P(X)	F(X)	I	X	P(X)	F(X)	I	X	P(X)	F(X)
1	0.00	0.0000	0.0000	1	0.00	0.0000	0.0000	1	0.00	0.0000	0.0000
2	0.25	0.0000	0.0000	2	0.25	0.0000	0.0000	2	0.25	0.0000	0.0000
3	0.50	0.0000	0.0000	3	0.50	0.0000	0.0000	3	0.50	0.0000	0.0000
4	0.75	0.0000	0.0000	4	0.75	0.0000	0.0000	4	0.75	0.0000	0.0000
5	1.00	0.0000	0.0000	5	1.00	0.0000	0.0000	5	1.00	0.0000	0.0000
6	1.25	0.0000	0.0000	6	1.25	0.0000	0.0000	6	1.25	0.0000	0.0000
7	1.50	0.0000	0.0000	7	1.50	0.0000	0.0000	7	1.50	0.0000	0.0000
8	1.75	0.0000	0.0000	8	1.75	0.0000	0.0000	8	1.75	0.0000	0.0000
9	2.00	0.0000	0.0000	9	2.00	0.0000	0.0000	9	2.00	0.0000	0.0000
10	2.25	0.0000	0.0000	10	2.25	0.0000	0.0000	10	2.25	0.0000	0.0000
11	2.50	0.0000	0.0000	11	2.50	0.0000	0.0000	11	2.50	0.0000	0.0000
12	2.75	0.0000	0.0000	12	2.75	0.0000	0.0000	12	2.75	0.0000	0.0000
13	3.00	0.0000	0.0000	13	3.00	0.0000	0.0000	13	3.00	0.0000	0.0000
14	3.25	0.0000	0.0000	14	3.25	0.0000	0.0000	14	3.25	0.0000	0.0000
15	3.50	0.0000	0.0000	15	3.50	0.0000	0.0000	15	3.50	0.0000	0.0000
16	3.75	0.0000	0.0000	16	3.75	0.0000	0.0000	16	3.75	0.0000	0.0000
17	4.00	0.0000	0.0000	17	4.00	0.0000	0.0000	17	4.00	0.0000	0.0000
18	4.25	0.0000	0.0000	18	4.25	0.0000	0.0000	18	4.25	0.0000	0.0000
19	4.50	0.0000	0.0000	19	4.50	0.0000	0.0000	19	4.50	0.0000	0.0000
20	4.75	0.0000	0.0000	20	4.75	0.0000	0.0000	20	4.75	0.0000	0.0000
21	5.00	0.0000	0.0000	21	5.00	0.0000	0.0000	21	5.00	0.0000	0.0000
22	5.25	0.0000	0.0000	22	5.25	0.0000	0.0000	22	5.25	0.0000	0.0000
23	5.50	0.0000	0.0000	23	5.50	0.0000	0.0000	23	5.50	0.0000	0.0000
24	5.75	0.0000	0.0000	24	5.75	0.0000	0.0000	24	5.75	0.0000	0.0000
25	6.00	0.0000	0.0000	25	6.00	0.0000	0.0000	25	6.00	0.0000	0.0000
26	6.25	0.0000	0.0000	26	6.25	0.0000	0.0000	26	6.25	0.0000	0.0000
27	6.50	0.0000	0.0000	27	6.50	0.0000	0.0000	27	6.50	0.0000	0.0000
28	6.75	0.0000	0.0000	28	6.75	0.0000	0.0000	28	6.75	0.0000	0.0000
29	7.00	0.0000	0.0000	29	7.00	0.0000	0.0000	29	7.00	0.0000	0.0000
30	7.25	0.0000	0.0000	30	7.25	0.0000	0.0000	30	7.25	0.0000	0.0000
31	7.50	0.0000	0.0000	31	7.50	0.0000	0.0000	31	7.50	0.0000	0.0000
32	7.75	0.0000	0.0000	32	7.75	0.0000	0.0000	32	7.75	0.0000	0.0000
33	8.00	0.0000	0.0000	33	8.00	0.0000	0.0000	33	8.00	0.0000	0.0000
34	8.25	0.0000	0.0000	34	8.25	0.0000	0.0000	34	8.25	0.0000	0.0000
35	8.50	0.0000	0.0000	35	8.50	0.0000	0.0000	35	8.50	0.0000	0.0000
36	8.75	0.0000	0.0000	36	8.75	0.0000	0.0000	36	8.75	0.0000	0.0000
37	9.00	0.0000	0.0000	37	9.00	0.0000	0.0000	37	9.00	0.0000	0.0000
38	9.25	0.0000	0.0000	38	9.25	0.0000	0.0000	38	9.25	0.0000	0.0000
39	9.50	0.0000	0.0000	39	9.50	0.0000	0.0000	39	9.50	0.0000	0.0000
40	9.75	0.0000	0.0000	40	9.75	0.0000	0.0000	40	9.75	0.0000	0.0000
41	10.00	0.0000	0.0000	41	10.00	0.0000	0.0000	41	10.00	0.0000	0.0000
42	10.25	0.0000	0.0000	42	10.25	0.0000	0.0000	42	10.25	0.0000	0.0000
43	10.50	0.0000	0.0000	43	10.50	0.0000	0.0000	43	10.50	0.0000	0.0000
44	10.75	0.0000	0.0000	44	10.75	0.0000	0.0000	44	10.75	0.0000	0.0000
45	11.00	0.0000	0.0000	45	11.00	0.0000	0.0000	45	11.00	0.0000	0.0000
46	11.25	0.0000	0.0000	46	11.25	0.0000	0.0000	46	11.25	0.0000	0.0000
47	11.50	0.0000	0.0000	47	11.50	0.0000	0.0000	47	11.50	0.0000	0.0000
48	11.75	0.0000	0.0000	48	11.75	0.0000	0.0000	48	11.75	0.0000	0.0000
49	12.00	0.0000	0.0000	49	12.00	0.0000	0.0000	49	12.00	0.0000	0.0000
50	12.25	0.0000	0.0000	50	12.25	0.0000	0.0000	50	12.25	0.0000	0.0000
51	12.50	0.0000	0.0000	51	12.50	0.0000	0.0000	51	12.50	0.0000	0.0000
52	12.75	0.0000	0.0000	52	12.75	0.0000	0.0000	52	12.75	0.0000	0.0000
53	13.00	0.0000	0.0000	53	13.00	0.0000	0.0000	53	13.00	0.0000	0.0000
54	13.25	0.0000	0.0000	54	13.25	0.0000	0.0000	54	13.25	0.0000	0.0000
55	13.50	0.0000	0.0000	55	13.50	0.0000	0.0000	55	13.50	0.0000	0.0000
56	13.75	0.0000	0.0000	56	13.75	0.0000	0.0000	56	13.75	0.0000	0.0000
57	14.00	0.0000	0.0000	57	14.00	0.0000	0.0000	57	14.00	0.0000	0.0000
58	14.25	0.0000	0.0000	58	14.25	0.0000	0.0000	58	14.25	0.0000	0.0000
59	14.50	0.0000	0.0000	59	14.50	0.0000	0.0000	59	14.50	0.0000	0.0000
60	14.75	0.0000	0.0000	60	14.75	0.0000	0.0000	60	14.75	0.0000	0.0000
61	15.00	0.0000	0.0000	61	15.00	0.0000	0.0000	61	15.00	0.0000	0.0000
62	15.25	0.0000	0.0000	62	15.25	0.0000	0.0000	62	15.25	0.0000	0.0000
63	15.50	0.0000	0.0000	63	15.50	0.0000	0.0000	63	15.50	0.0000	0.0000
64	15.75	0.0000	0.0000	64	15.75	0.0000	0.0000	64	15.75	0.0000	0.0000
65	16.00	0.0000	0.0000	65	16.00	0.0000	0.0000	65	16.00	0.0000	0.0000
66	16.25	0.0000	0.0000	66	16.25	0.0000	0.0000	66	16.25	0.0000	0.0000
67	16.50	0.0000	0.0000	67	16.50	0.0000	0.0000	67	16.50	0.0000	0.0000
68	16.75	0.0000	0.0000	68	16.75	0.0000	0.0000	68	16.75	0.0000	0.0000
69	17.00	0.0000	0.0000	69	17.00	0.0000	0.0000	69	17.00	0.0000	0.0000
70	17.25	0.0000	0.0000	70	17.25	0.0000	0.0000	70	17.25	0.0000	0.0000
71	17.50	0.0000	0.0000	71	17.50	0.0000	0.0000	71	17.50	0.0000	0.0000
72	17.75	0.0000	0.0000	72	17.75	0.0000	0.0000	72	17.75	0.0000	0.0000
73	18.00	0.0000	0.0000	73	18.00	0.0000	0.0000	73	18.00	0.0000	0.0000
74	18.25	0.0000	0.0000	74	18.25	0.0000	0.0000	74	18.25	0.0000	0.0000
75	18.50	0.0000	0.0000	75	18.50	0.0000	0.0000	75	18.50	0.0000	0.0000
76	18.75	0.0000	0.0000	76	18.75	0.0000	0.0000	76	18.75	0.0000	0.0000
77	19.00	0.0000	0.0000	77	19.00	0.0000	0.0000	77	19.00	0.0000	0.0000
78	19.25	0.0000	0.0000	78	19.25	0.0000	0.0000	78	19.25	0.0000	0.0000
79	19.50	0.0000	0.0000	79	19.50	0.0000	0.0000	79	19.50	0.0000	0.0000
80	19.75	0.0000	0.0000	80	19.75	0.0000	0.0000	80	19.75	0.0000	0.0000
81	20.00	0.0000	0.0000	81	20.00	0.0000	0.0000	81	20.00	0.0000	0.0000
82	20.25	0.0000	0.0000	82	20.25	0.0000	0.0000	82	20.25	0.0000	0.0000
83	20.50	0.0000	0.0000	83	20.50	0.0000	0.0000	83	20.50	0.0000	0.0000
84	20.75	0.0000	0.0000	84	20.75	0.0000	0.0000	84	20.75	0.0000	0.0000
85	21.00	0.0000	0.0000	85	21.00	0.0000	0.0000	85	21.00	0.0000	0.0000
86	21.25	0.0000	0.0000	86	21.25	0.0000	0.0000	86	21.25	0.0000	0.0000
87	21.50	0.0000	0.0000	87	21.50	0.0000	0.0000	87	21.50	0.0000	0.0000
88	21.75	0.0000	0.0000	88	21.75	0.0000	0.0000	88	21.75	0.0000	0.0000
89	22.00	0.0000	0.0000	89	22.00	0.0000	0.0000	89	22.00	0.0000	0.0000
90	22.25	0.0000	0.0000	90	22.25	0.0000	0.0000	90	22.25	0.0000	0.0000
91	22.50	0.0000	0.0000	91	22.50	0.0000	0.0000	91	22.50	0.0000	0.0000
92	22.75	0.0000	0.0000	92	22.75	0.0000	0.0000	92	22.75	0.0000	0.0000
93	23.00	0.0000	0.0000	93	23.00	0.0000	0.0000	93	23.00	0.0000	0.0000
94	23.25	0.0000	0.0000	94	23.25	0.0000	0.0000	94	23.25	0.0000	0.0000
95	23.50	0.0000	0.0000	95	23.50	0.0000	0.0000	95	23.50	0.0000	0.0000
96	23.75										

3. Duration Statistics. These statistics are featured on two plots for each station, one for the total water level and one for the storm surge. Duration is the length of time a water level will remain above a certain level once that level has been exceeded. An example is given in Figure 3 where the lower line is the average duration and the upper line is the maximum duration. For example, when the total water level at Boston exceeds 4.0 feet, it will remain above this level for about 2.6 hours on the average and for about 6.5 hours at the maximum. This information is useful for cases where a certain water level can be tolerated for a specified length of time.

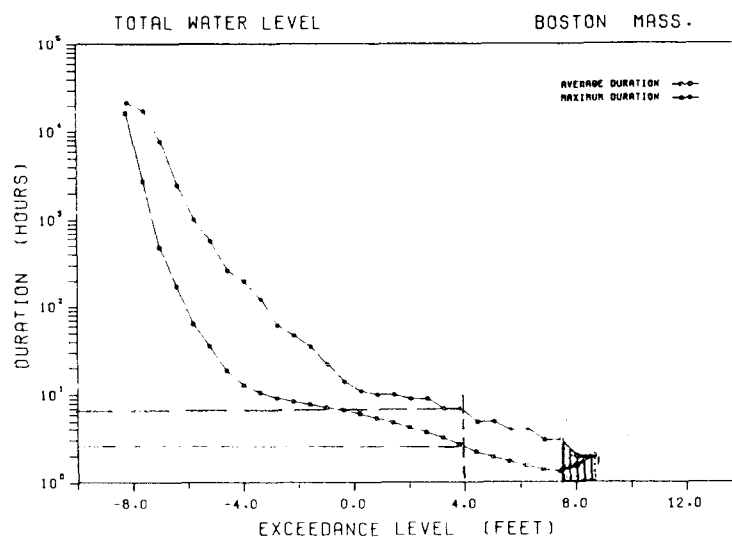


Figure 3: Example of Duration Plots

Report 7 points out that the maximum duration values might be slightly conservative, and cautions about interpreting results from the shaded region of the plot (see Figure 3).

4. Extreme Storm Surge Data. A theory was developed for extreme storm surge probability prediction using the monthly maxima of surge measured at each tidal reference station. Each station has 13 figures, one for the yearly maxima and 12 for the monthly extremes. An example is given in Figure 4, where a return period of 10 years corresponds to an extreme storm surge of about 3 feet.

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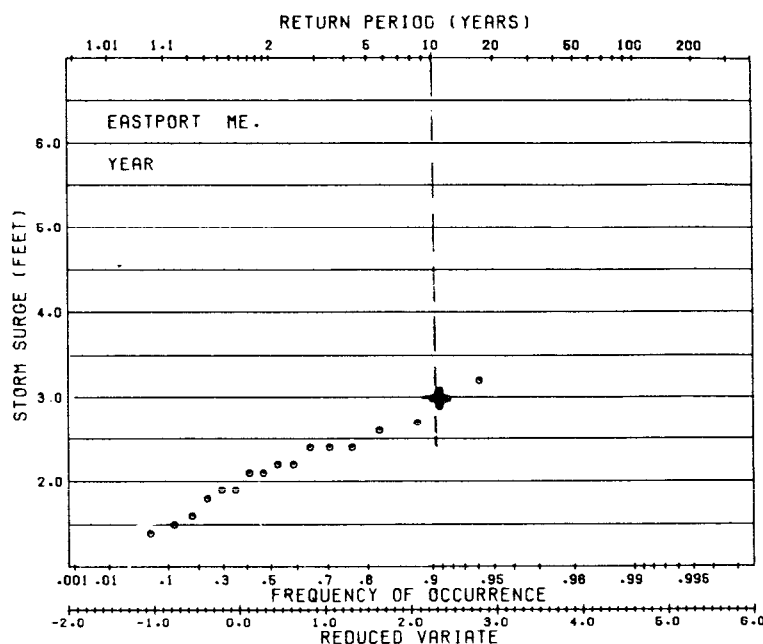


Figure 4: Example of Extreme Storm Surge Probability.

Report 7 discusses the development of these figures, and the possible sources of error. A method is given to determine the confidence limits, and these should be used when determining extreme storm surges from these tables. Work is in progress on a WIS Report that will contain statistics of large storm surges due to both tropical and extratropical storm. Therefore, the extreme storm surge data presented in Report 7 should be considered as interim design guidance.

ESTIMATES FOR OTHER ATLANTIC COAST SITES: The joint probability distribution of tides and surges for locations other than the 20 sites given in the table can be computed using the method suggested by Harris (1981). First, the distribution of tidal elevation probabilities at the desired location is generated from the known probability distribution of a nearby station. This involves multiplying the known distribution by the ratio of the mean tide ranges at the two sites. An example of this procedure is given in CETN I-13. Second, the surge probability distribution at a specific site can be given as a simple linear interpretation between two adjacent sites for which statistics are known. This can be done with reasonable accuracy since the storm surge statistics vary only slightly from station to station. Finally, the joint tide and storm surge probability distribution is obtained using the procedure given in Harris (1981) on pages 82-85.

REFERENCES:

- EBERSOLE, B. A., "Atlantic Coast Water-Level Climate," WIS Report 7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, April 1982.
- HARRIS, D. L., "Tides and Tidal Datum in the United States," SR-7, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Virginia, February 1981.
- U.S. ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, "Calculating Tidal Elevation Probabilities," CETN-I-13, Fort Belvoir, Virginia, 1981.